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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

SPIN TESTS OF $\frac{1}{20}$ -SCALE MODELS OF THE CHANCE VUGHT

REVISED XF6U-1 AND F6U-1 AIRPLANES

TED NO. NACA 2390

By

Walter J. Kliner and Theodore Berman

Langley Aeronautical Laboratory
Langley Field, Va.

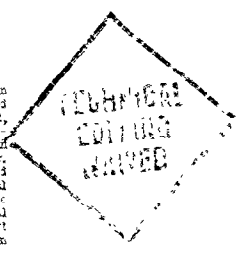
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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on the $\frac{1}{20}$ -scale model of the Chance Vought XF6U-1 airplane altered to represent the XF6U-1 airplane as it will be spin-tested in flight, and also altered to represent the F6U-1 airplane as it will be produced for service use. Spin tests were made to determine the effects of control settings and movements at the normal loading.

The results show that the spins obtained on the revised XF6U-1 airplane will be oscillatory in roll and yaw and that recoveries by rudder reversal will be rapid. Model test results indicate that the F6U-1 airplane will probably not spin. Inasmuch as the results of this investigation show that the new designs are as good as or better than the original XF6U-1 design in regard to spin recovery, it is felt that the conclusions and recommendations reached for the original design can be applied to the new designs for all loading conditions.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Department of the Navy, tests were performed in the Langley 20-foot free-spinning tunnel to determine the effect on the spin and recovery characteristics of modifications to the design of the original Chance Vought XF6U-1 airplane. A $\frac{1}{20}$ -scale model of the XF6U-1 which was previously tested in the spin tunnel (reference 1) was modified to represent a revised version of the XF6U-1 and the production version F6U-1, respectively.

The important change as regards spinning that has been made during the development of the original XF6U-1 to the later versions of the

airplane is that the portion of the rudder extending below the horizontal tail on the original XF6U-1 has been fixed to the vertical fin. This resulted in a condition for which the entire rudder was in a shielded region under normal spin conditions, which normally would indicate that the revised design would have poor tail design for recovery from the spin. It was primarily to evaluate the effects of this change in tail design that the current tests were performed. The effects of maximum and intermediate control deflections on the erect spin and recovery characteristics of both new designs were determined for their normal-loading conditions.

SYMBOLS

b	wing span, feet
S	wing area, square feet
\bar{c}	mean aerodynamic chord, feet
x/\bar{c}	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
z/\bar{c}	ratio of distance between center of gravity and thrust line to mean aerodynamic chord (positive when center of gravity is below thrust line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X-, Y-, and Z-body axes, respectively, slug-feet ²
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs per cubic foot
μ	relative density of airplane $\left(\frac{m}{\rho S b} \right)$

APPARATUS AND METHODS

Model

The $\frac{1}{20}$ -scale model of the XF6U-1 used for the previous tests was modified to represent the new configurations by the Langley Laboratory. A comparison drawing of the original XF6U-1 and the revised XF6U-1 models is shown in figure 1. Figure 2 is a three-view drawing of the model of the production F6U-1 airplane. Photographs of the model are shown in figures 3 and 4.

The new XF6U-1 configuration differs from the original mainly in tail design. A large dorsal fin, horizontal-tail leading-edge fillets, and a "torpedo" fairing at the vertical- and horizontal-tail intersection were added to the original design and the portion of the original rudder below the horizontal tail was fixed at neutral. In addition, the distribution of mass along the fuselage was increased somewhat.

The F6U-1, the production airplane, in addition to the changes enumerated above, has an afterburner installed, an increase in nose length of 60.5 inches, and a small increase in the height of the vertical tail. The mass distribution along the fuselage was now greater than for either of the XF6U-1 designs but the change was not very large.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ slug/cu ft). A remote-control mechanism was installed in the model to actuate the controls for recovery tests and sufficient moments were exerted on the control surfaces during recovery tests to reverse the controls rapidly to the desired setting.

Wind Tunnel and Testing Technique

The technique used for obtaining and converting data on the revised XF6U-1 and the F6U-1 models tested was the same as that used for the original XF6U-1 model (references 1 and 2).

PRECISION

The model test results presented herein are believed to be the true values given by the model within the following limits:

V, percent	± 5
Turns for recovery	$\pm \frac{1}{4}$ turn

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and airplane spin results (references 2 and 3) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the model spins at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and with 5° to 10° more outward sideslip than the airplane. The comparison made in reference 3 showed that approximately 80 percent of the model recovery tests predicted satisfactorily the corresponding airplane recoveries and that 10 percent overestimated and 10 percent underestimated the turns for recovery.

Because of the impracticability of exact ballasting of the model and because of inadvertent damage to the model during the tests, the measured weight and mass distributions of the model varied from the true scaled-down values by the following amounts:

Weight, percent	0
Center-of-gravity location, percent \bar{c}	0
I_x , percent	0 to 4 high
I_y , percent	0 to 8 low
I_z , percent	0 to 5 low

The accuracy of measuring the weight and mass distribution is believed to be within the following limits:

Weight, percent	± 1
Center-of-gravity location, percent \bar{c}	± 1
Moments of inertia, percent	± 5

The controls were set with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

Because of the similarity of the revised XF6U-1, the F6U-1, and the original XF6U-1 designs, tests of the new configurations were limited to those in the normal loadings, clean (flaps and landing gear retracted) condition. A dimensional comparison of the three designs is given in table I. The mass characteristics and inertia parameters of the normal loadings of the airplanes and of the model as tested are shown in table II. The inertia parameters have been plotted on figure 5 which, as discussed in reference 4, can be used as an aid in predicting the effects of controls on the spin and recovery characteristics of the model.

The tail-damping power factor of the airplanes, computed by the method described in reference 5, is zero for both new configurations. For the original XF6U-1, the tail-damping power factor was 0.000803.

The maximum control deflections used for the current tests were:

Rudder, degrees 20 right, 20 left
Elevator, degrees 25 up, 20 down
Ailerons, degrees 17 up, 17 down

The intermediate control deflections used were:

Rudder 2/3 deflected, degrees 13
Elevator 2/3 up, degrees 17
Ailerons 1/3 deflected, degrees 6 up, 6 down

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented on charts 1 and 2. The model data are presented in terms of the full-scale values for the airplane at a test altitude of 15,000 feet.

Preliminary tests of the model showed that recoveries from right and left spins were similar, and results are, therefore, arbitrarily presented in terms of right spins.

Revised XF6U-1

The test results obtained with the XF6U-1 model revised to simulate the XF6U-1 airplane as it is to be spin-tested in flight are presented in chart 1. The results obtained were generally similar to the original model results (reference 1) in that the spins were all oscillatory in roll and yaw, some being so oscillatory that the model either rolled or dived out of the spin without movement of the controls. From the spins that were obtained, recovery was rapid by rudder reversal. The test results also showed that merely neutralizing the rudder would insure satisfactory recoveries from spins obtained at the normal-spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin).

It might be expected that this model would exhibit very poor spin-recovery characteristics because of zero value of tail-damping power factor. The results indicate, however, that the oscillations encountered by the model during the spins apparently move the tail into such positions that the rudder above the horizontal tail becomes at least temporarily unshielded and thus effective in terminating the original spin rotation. It appears, therefore, that the airplane spin will be oscillatory and recovery satisfactory in spite of the low value of tail-damping power factor.

The F6U-1

The test results obtained with the simulated F6U-1 model are presented in chart 2. When this model was launched into the tunnel in a spinning attitude, it oscillated until it either rolled or dived out of the spin without movement of the controls for nearly all control configurations. A spin was obtained only when the ailerons were placed with the spin and the elevator was set to neutral, and satisfactory recoveries were obtained by reversal of the rudder at this control setting. The results indicate therefore that the F6U-1 airplane will probably not spin.

Effect of Installing Wing-Tip Fuel Tanks

Though specific model tests were not conducted with wing-tip fuel tanks installed, an analysis of the probable results was made based on the original XF6U-1 results with wing-tip fuel tanks added. The test results reported in reference 1 and data in reference 6 pertaining to oscillations in the spin indicate that in a spin with full wing-tip tanks installed, the test airplanes will not oscillate in roll and yaw as for the normal loading but will spin with a pitching oscillation and that recovery by rudder reversal alone will probably not be satisfactory. It does appear, however, that full reversal of the rudder and elevator should effect satisfactory recovery. It is possible that for some conditions when the external tanks are only partially filled, both the rudder and elevator will be insufficiently effective in providing recovery from the spins that may be obtained. If the airplanes experience any difficulty in recovering from a spin when the external fuel tanks are installed, the following procedure is recommended: Jettison the tanks, set the rudder with the spin and return the elevator to its full-up position, then reverse the rudder fully and rapidly.

Inverted Spins

No inverted-spin tests were conducted on the models; but based on the test results obtained with the original XF6U-1 model (presented in reference 1), it appears that inverted spins obtained on the revised XF6U-1 and F6U-1 airplane will be wandering and oscillatory and that recovery by full rudder reversal from these spins will be satisfactory. Neutralization of all controls should satisfactorily terminate any inverted spin obtained.

CONCLUSIONS

Based on results of spin tests of a $\frac{1}{20}$ -scale model modified to represent the Chance Vought XF6U-1 (revised) and F6U-1 airplanes, the following conclusions regarding the spin and recovery characteristics of either airplane at 15,000 feet are made:

1. For the normal fighter loading, the XF6U-1 airplane spins will be oscillatory in roll and yaw and recoveries by rudder reversal will be satisfactory. The F6U-1 airplane will probably not spin.

2. The spin and recovery characteristics for all loading conditions will be similar to those reported for the original XF6U-1. The conclusions and recommendations made for the original XF6U-1, which apply generally to the new designs, are:

(a) Moving the center of gravity forward will tend to cause the airplane to spin somewhat less violently, whereas moving the center of gravity rearward will tend to accentuate the oscillations in the spin.

(b) When full wing-tip fuel tanks are installed, full elevator reversal will probably be required in conjunction with rudder reversal to insure satisfactory recovery. If recovery does not appear imminent after a recovery attempt is made, the tanks should be jettisoned.

(c) Satisfactory recoveries from inverted spins will be obtained by neutralizing all controls.

(d) A 5-foot wing parachute or an 8-foot tail parachute (drag coefficient 0.77 and 0.68, respectively) will be effective for emergency recoveries from demonstration spins.

(e) If it is necessary for the pilot to abandon the spinning airplane, he should attempt escape from the outboard side during the flat phase of the oscillation. Because of the erratic oscillatory motion indicated for the airplane during the spin, it may be advisable to provide positive ejection mechanism for the pilot to insure that he clears the airplane.

(f) The rudder-pedal force required to effect a recovery will probably be within the capabilities of the pilot.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE ORIGINAL XF6U-1, THE
REVISED XF6U-1, AND THE F6U-1 AIRPLANE

	Original XF6U-1	Revised XF6U-1	F6U-1
Length over all, ft	32.83	33.96	39.0
Normal center-of-gravity location, percent \bar{c}	31.03	29.78	27.54
Wing:			
Span, ft	32.83	32.83	32.83
Area, sq ft	203.5	203.5	203.5
Section, root	NACA 65(215)-114	NACA 65(215)-114	NACA 65(215)-114
Section, tip	NACA 65 ₁ -212, $a = 0.6$	NACA 65 ₁ -212, $a = 0.6$	NACA 65 ₁ -212, $a = 0.6$
Root-chord incidence, deg	2.0	2.0	2.0
Tip-chord incidence, deg	-1.0	-1.0	-1.0
Aspect ratio	5.3	5.3	5.3
Dihedral, deg	4.0	4.0	4.0
Mean aerodynamic chord, in.	77.5	77.5	77.5
Leading edge \bar{c} aft leading-edge root chord, in.	6.75	6.75	6.75
Flaps:			
Total area, sq ft	33.6	33.6	33.6
Span, percent $b/2$	50.0	50.0	50.0
Ailerons:			
Total area, sq ft	20.4	20.4	20.4
Span, percent $b/2$	36.1	36.1	36.1
Horizontal tail surfaces:			
Total area, including fillets, sq ft	45.8	52.8	52.8
Span, ft	14.3	14.3	14.3
Elevator area, sq ft	15.0	15.0	15.0
Distance from normal center of gravity to elevator hinge line, ft	16.19	16.27	16.42
Vertical tail surfaces:			
Total area, including dorsal fin, sq ft	26.6	34.8	37.4
Total rudder area, sq ft	9.4	5.8	6.9
Distance from normal center of gravity to rudder hinge line, ft	16.51	16.59	16.74
Tail-damping power factor	803 X 10 ⁻⁶	0	0

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TABLE II

LOADINGS OF THE ORIGINAL XF6U-1, THE REVISED XF6U-1, AND THE F6U-1 AIRPLANES AND OF THE $\frac{1}{20}$ -SCALE MODEL TESTED IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

[Moments of inertia about center of gravity; model values converted to corresponding full-scale values]

Loadings referred to in figure 5	Loading	Weight (lb)	Center-of-gravity location		μ		Moments of inertia			Mass parameters		
			x/\bar{c}	z/\bar{c}	Sea level	15,000 ft	I_x (slug-ft ²)	I_y (slug-ft ²)	I_z (slug-ft ²)	$\frac{I_x - I_y}{mb^2}$	$\frac{I_y - I_z}{mb^2}$	$\frac{I_z - I_x}{mb^2}$
			Airplane values									
1	Revised XF6U-1, normal loading	9,695	0.298	-0.077	18.9	30.1	3,762	13,779	16,763	-309×10^{-4}	-92×10^{-4}	401×10^{-4}
2	F6U-1, normal loading	10,562	.275	-.082	20.6	32.8	4,000	17,801	20,653	-390.	-81	471
3	Original XF6U-1, normal loading	9,025	.310	-.076	17.6	28.0	3,975	11,766	14,587	-258	-93	351
4	Original XF6U-1 with full wing tip fuel tanks	10,939	.327	-.0658	21.38	33.95	21,022	12,142	31,942	242	-540	298
Model values												
1	Revised XF6U-1, normal loading	9,711	0.298	-0.065	19.0	30.2	3,774	13,826	16,755	-309×10^{-4}	-91×10^{-4}	400×10^{-4}
2	F6U-1, normal loading	10,588	.275	-.079	20.7	32.9	3,850	16,394	19,644	-354	-92	446

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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$ SCALE MODEL OF THE REVISED CHANCE VOUGHT XF6U-1 AIRPLANE

IN THE NORMAL LOADING

[Normal loading; loading point 1 on table II and figure 5; flaps neutral; landing gear retracted; cockpit closed; right erect spin]

Model becomes increasingly oscillatory in yaw and roll until it dives out of the spin.	Steep spin. Oscillatory mainly in yaw. Vertical velocity: >310 ft/sec Full rudder reversal: $\frac{1}{4}$, $\frac{1}{2}$ Goes into a glide (Recoveries attempted before model in final steeper attitude) Neutralizing rudder: $\frac{1}{4}$, $\frac{1}{2}$ Goes into a glide (Recoveries attempted before model in final steeper attitude)	Steep spin, oscillatory in roll and yaw with a whip. Vertical velocity: >310 ft/sec $\frac{1}{4}$, $\frac{1}{2}$ Goes into erect glide with small amplitude rolling oscillation. (Recoveries attempted before model in final steeper attitude)
Model becomes increasingly oscillatory in pitch, yaw, and roll until outboard wing is yaved down approximately 90°, and then model goes into a left roll.	Spin oscillatory in roll and yaw. Vertical velocity: >310 ft/sec Rudder reversed to $\frac{2}{3}$ against the spin $\frac{1}{4}$, $\frac{1}{2}$ Goes into a dive (Recoveries attempted before model in final steeper attitude)	Steep spin, fairly steady. Vertical velocity: >310 ft/sec Rudder reversed to $\frac{2}{3}$ against the spin $\frac{1}{4}$, $\frac{1}{2}$ Goes into a dive (Recoveries attempted before model in final steeper attitude)
Model becomes increasingly oscillatory in pitch, yaw, and roll until outboard wing is yaved down approximately 90°, and then model goes into a left roll.	Model becomes increasingly oscillatory in yaw and roll until it dives out of the spin.	Steep spin with a whip. Vertical velocity: >310 ft/sec $\frac{1}{4}$, $\frac{1}{2}$ Goes into an inverted spin. (Recoveries attempted before model in final steeper attitude)
Model becomes increasingly oscillatory in pitch, yaw, and roll until outboard wing is yaved down approximately 90°, and then model goes into a left roll.	Model becomes increasingly oscillatory in yaw and roll until it dives out of the spin.	Steep spin with periodic whip. Vertical velocity: >310 ft/sec

Key to control settings:

- A - aileron
- E - elevator
- a - against
- n - neutral
- v - with
- u - up
- d - down

Aa Eu	An Eu	Av Eu
$\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$	$\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$	$\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$
Aa En	An En	Av En
Aa Ed	An Ed	Av Ed

Legend

Description of the model motion when the rudder is maintained full with the spin. Full-scale velocity given.
Number of turns required for recovery and description of flight path after recovery. All recoveries are by full rudder reversal unless otherwise indicated.

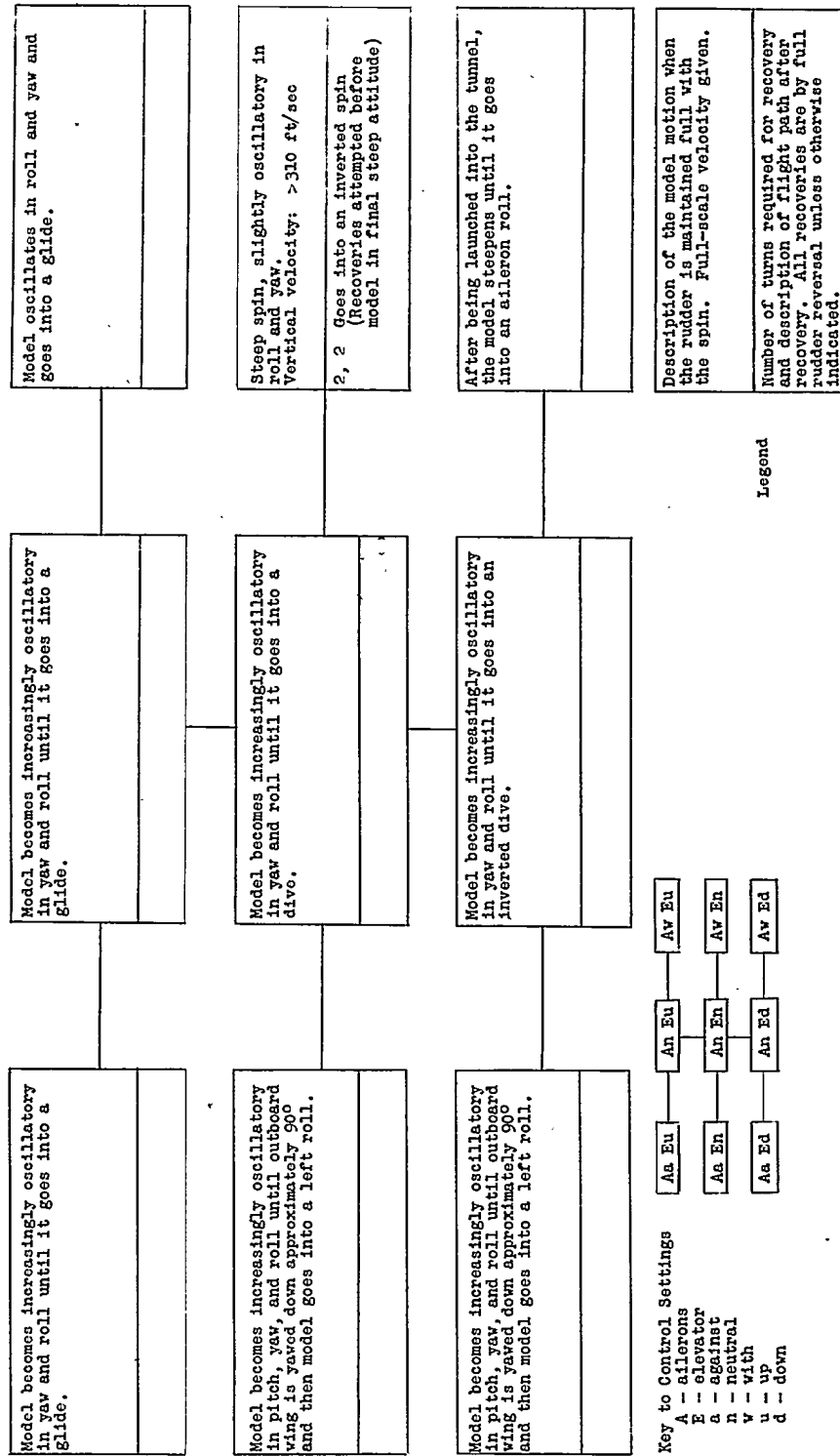
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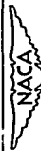
CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$ -SCALE MODEL OF THE CHANCE Vought F6U-1

AIRPLANE IN THE NORMAL LOADING

[Normal loading; loading point 2 on table II and figure 5; flaps neutral; landing gear retracted; cockpit closed; right erect spins]



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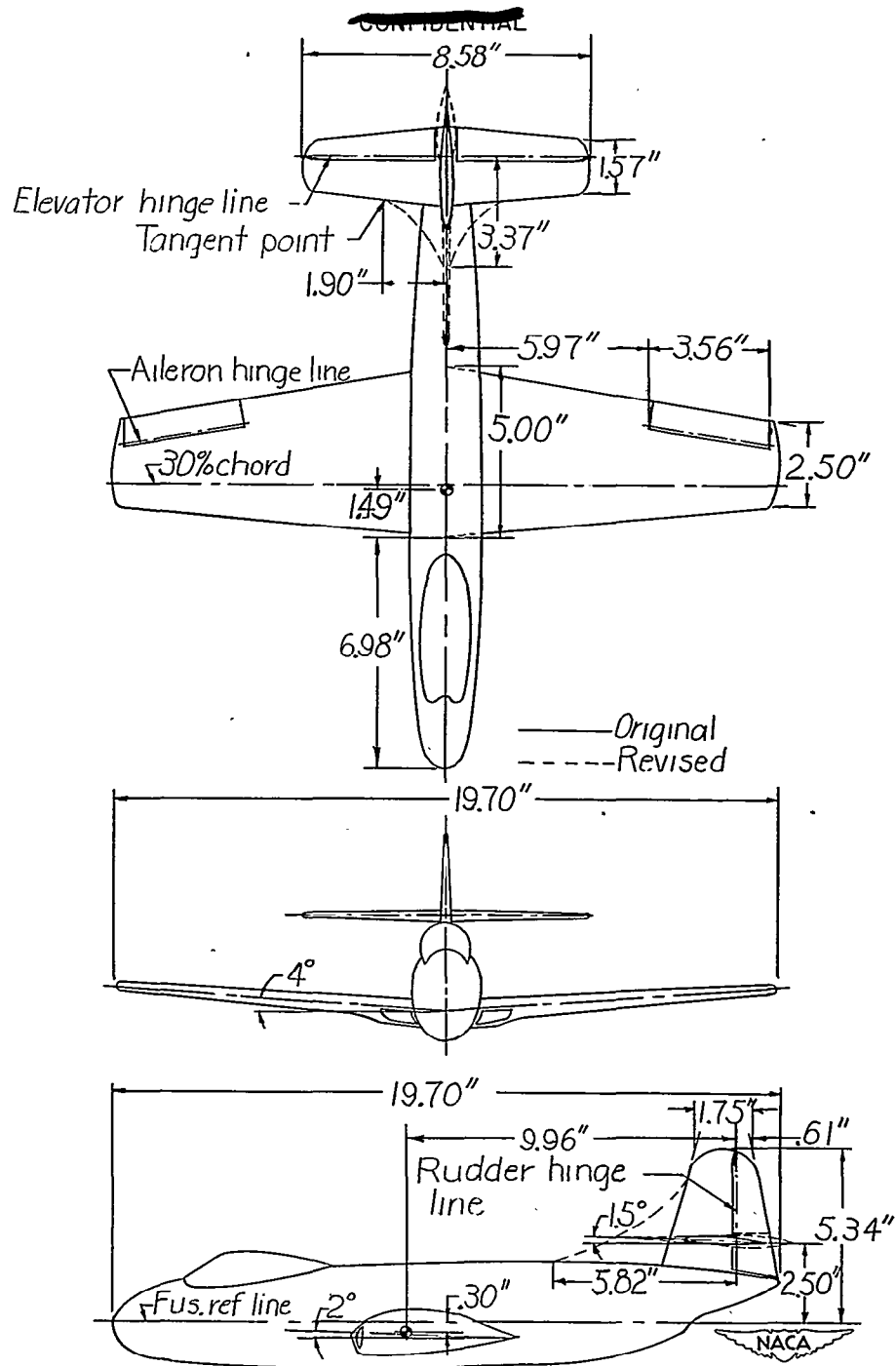


Figure 1.- Three-view comparison drawing of the $\frac{1}{20}$ -scale models of the original and revised Chance Vought XF6U-1 airplanes as tested in the Langley 20-foot free-spinning tunnel. Center-of-gravity location is shown for the normal loading.

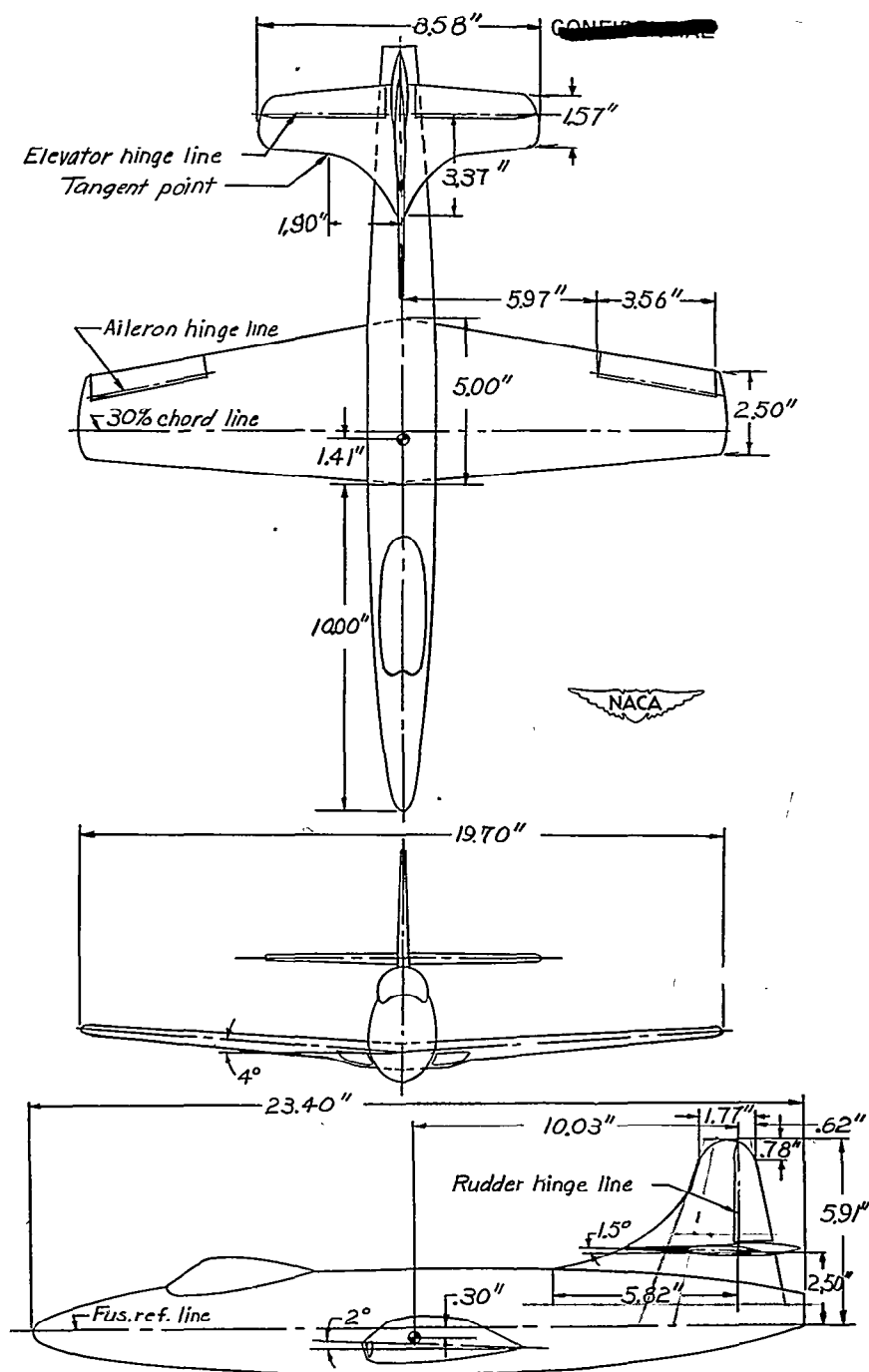


Figure 2.- Three-view drawing of the $\frac{1}{20}$ -scale model of the Chance Vought F6U-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Center-of-gravity location is shown for the normal loading.

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Figure 3.- Photograph of the $\frac{1}{20}$ -scale model of the revised Chance Vought XF6U-1 airplane.

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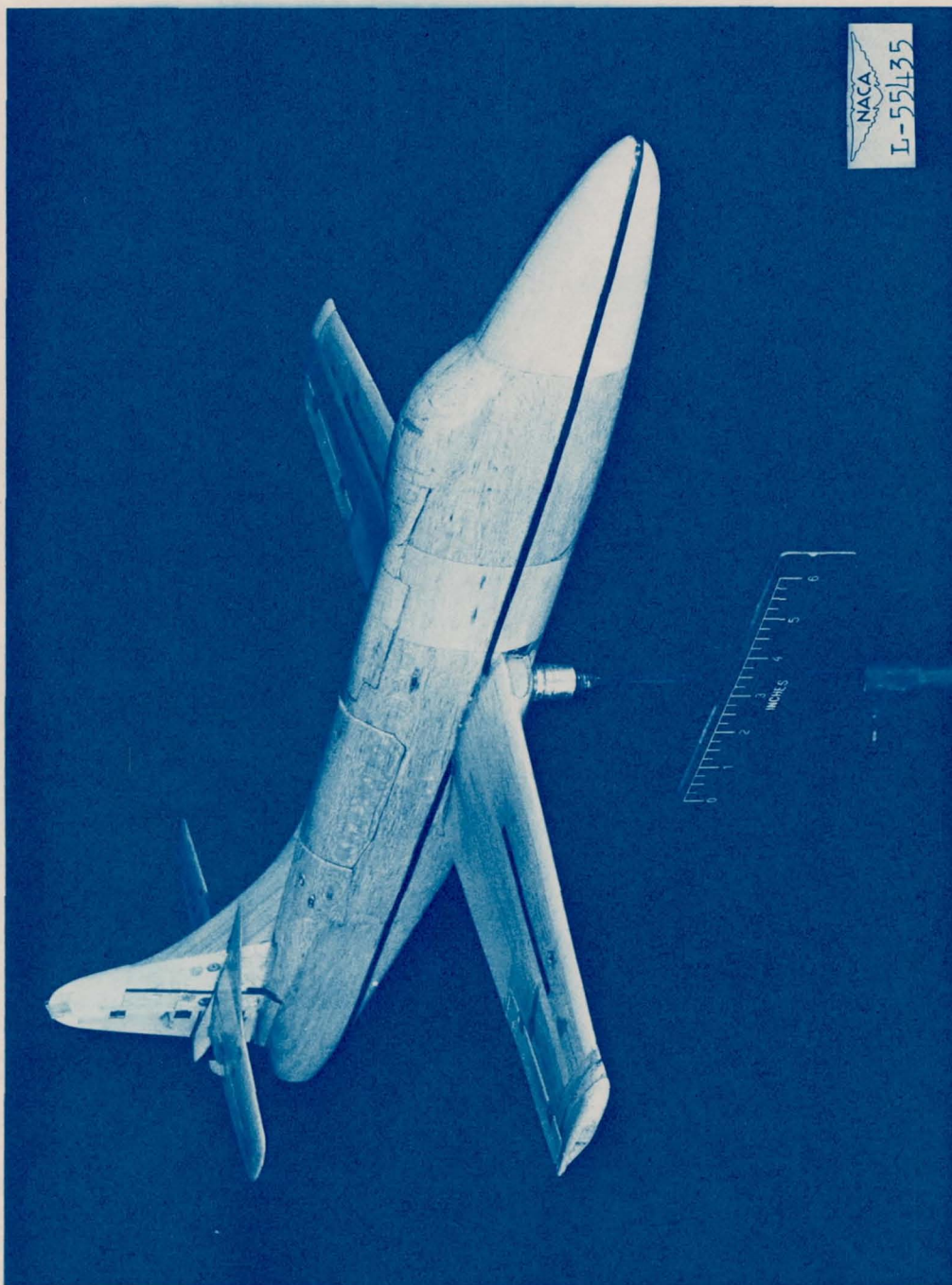


Figure 4.- Photograph of the $\frac{1}{20}$ -scale model of the Chance Vought F6U-1 airplane.

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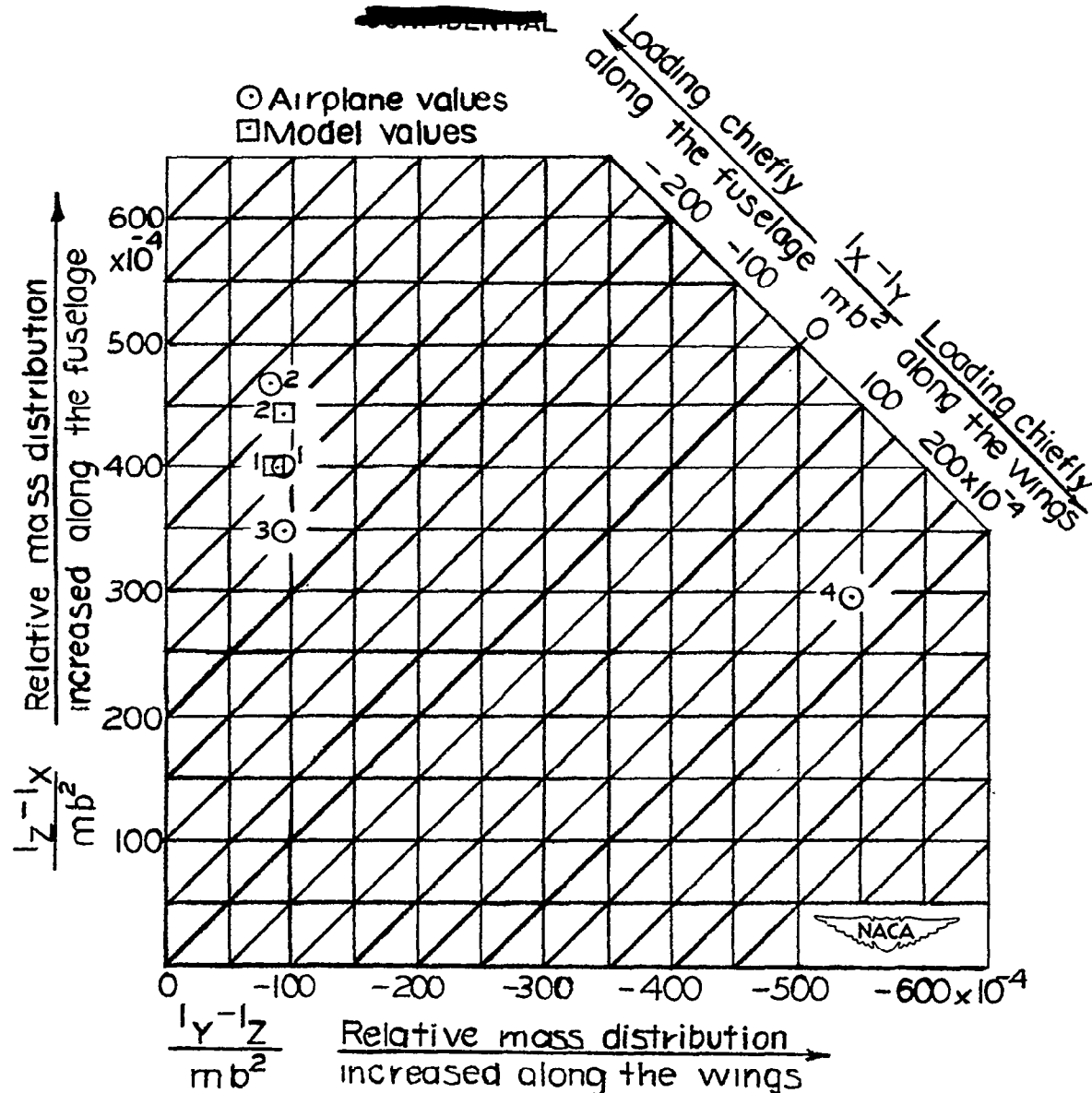


Figure 5.- Mass parameters for loadings possible on the Chance Vought XF6U-1 and F6U-1 airplanes and for loadings tested on the $\frac{1}{20}$ -scale model. (Points are for loadings listed in table II.)

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